Monte Carlo Simulations in Proton Therapy

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1. Abstract

Aims

- Evaluate role of Monte Carlo simulations in predicting neutron shielding effectiveness within a proton therapy environment
- Compare predictions from simulations where neutron sources behave differently

Conclusions

- Simulations most effective with isotropic neutron production
- This makes analysis process time consuming
- Monte Carlo simulations produce reasonable predictions
- Should be considered for use in a proton therapy environment

Deviation of Monte Carlo Neutron Ratios from Observed Lab Values

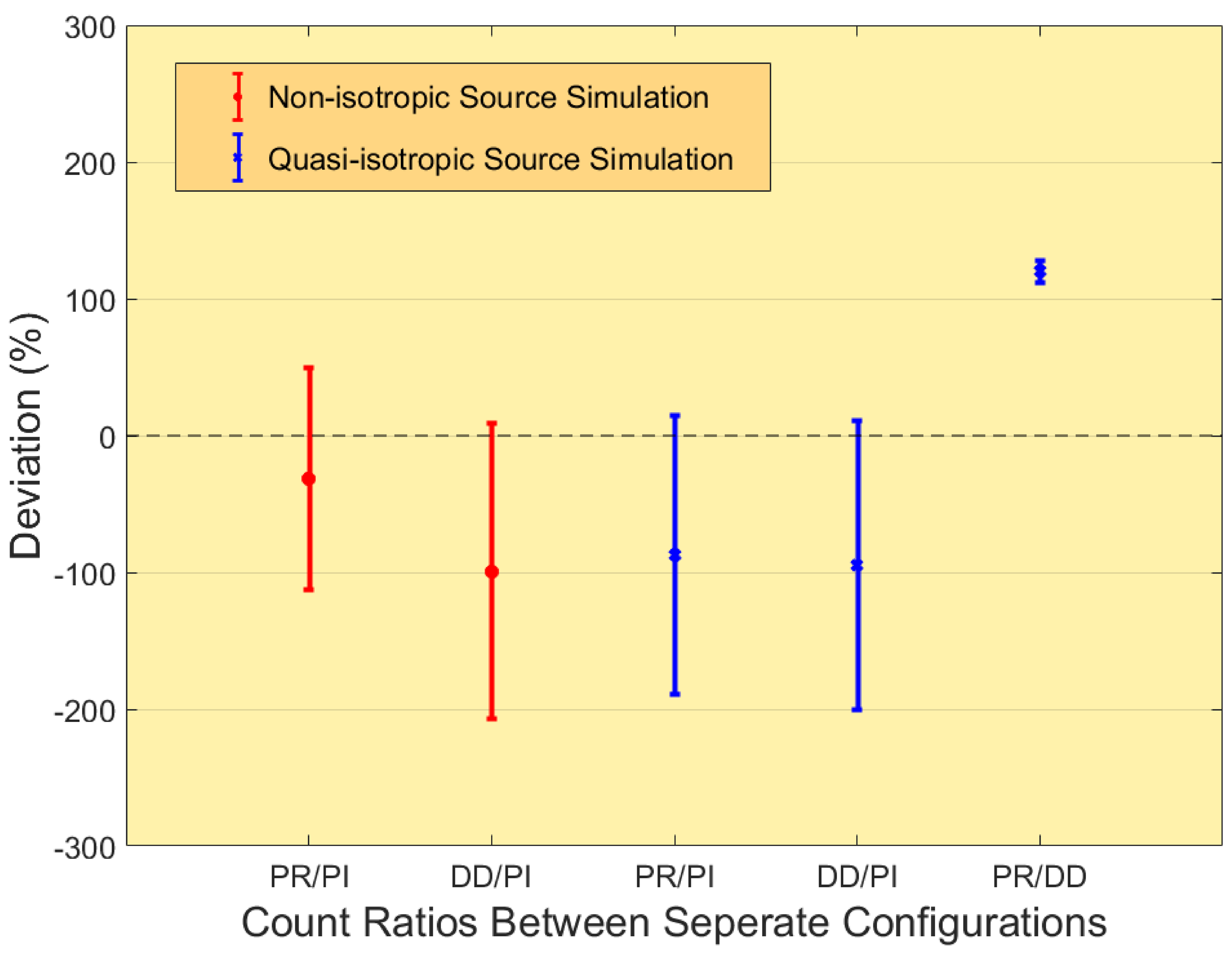

Figure 1. Comparison of Monte Carlo ratios with experimental values. Note that 'PR', 'PI' and 'DD' were the total numbers of neutron events recorded for the 'plug removed', 'plug inserted' and 'detector displaced' configurations respectively. The PR/DD ratio for the Non-isotropic simulation was omitted as its deviation was too large.

2. Motivation

Proton Therapy

- Tumours targeted with fine-tuned proton beam
- Protons stop and deposit energy within tumour
- Procedure generates secondary neutrons
- Neutrons difficult to stop and biologically effective
- Monte Carlo simulations could be used to assess neutron risk

Comparison of X-ray and Proton Therapy

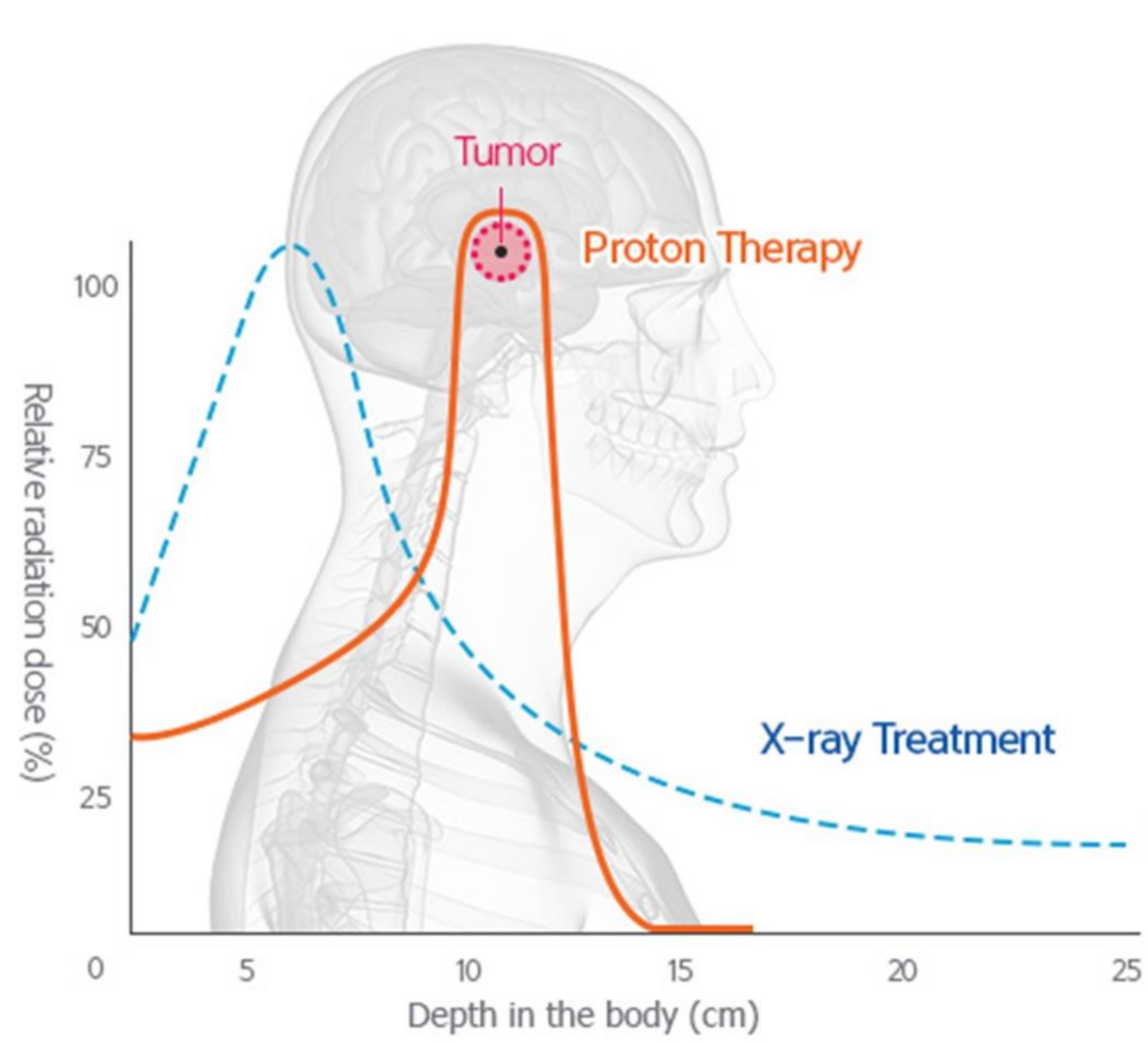

Figure 2. X-ray and proton therapy dose (Samsung Medical Centre)

3. Methods

Experimental Configurations

1) Detector centred opposite beam-port with polythene plug inserted
2) Same as first configuration but with plug removed
3) Detector displaced from centre of beam-port by 16cm with plug removed

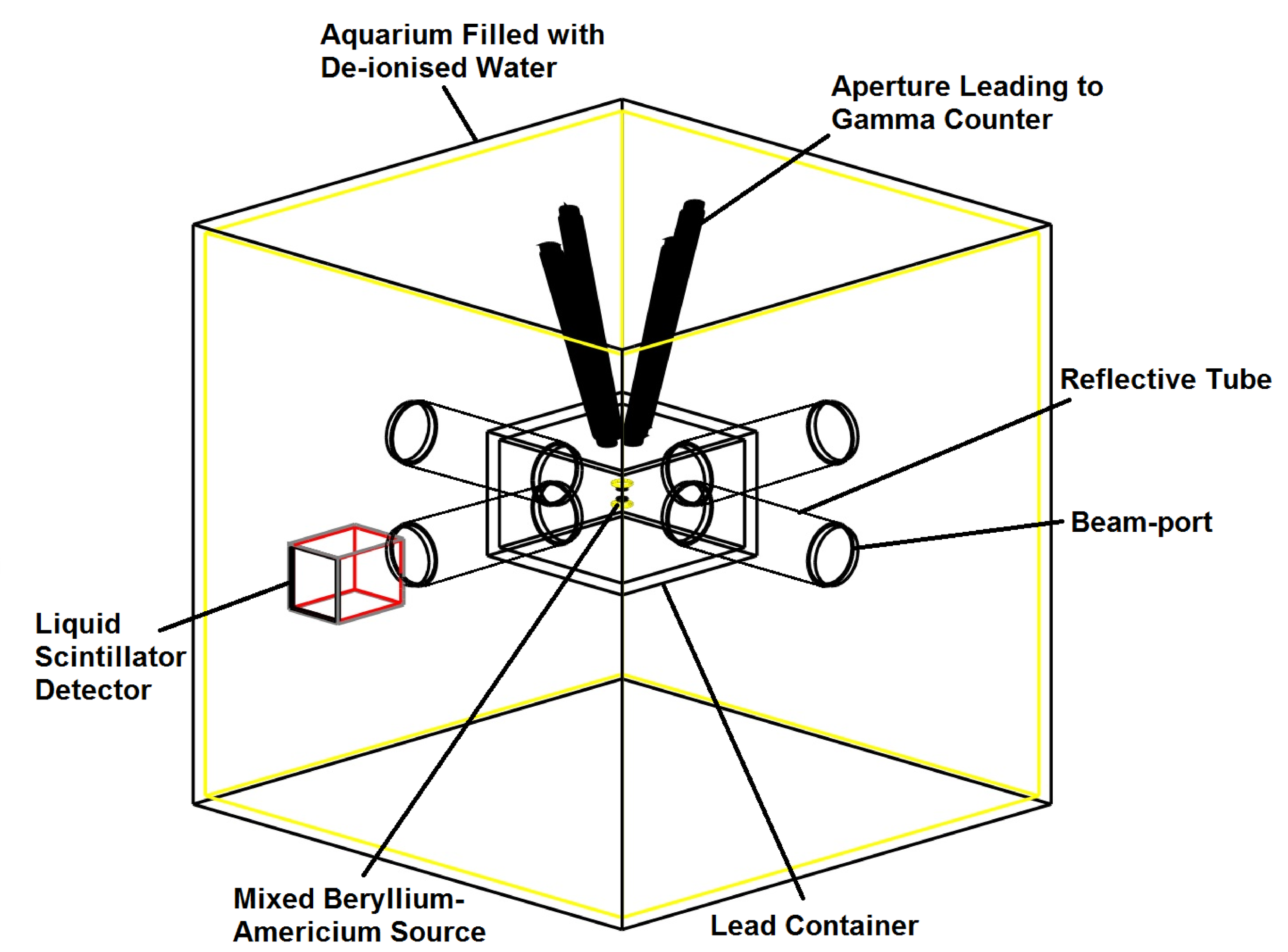

Figure 3. Water cube diagram

Monte Carlo Simulations

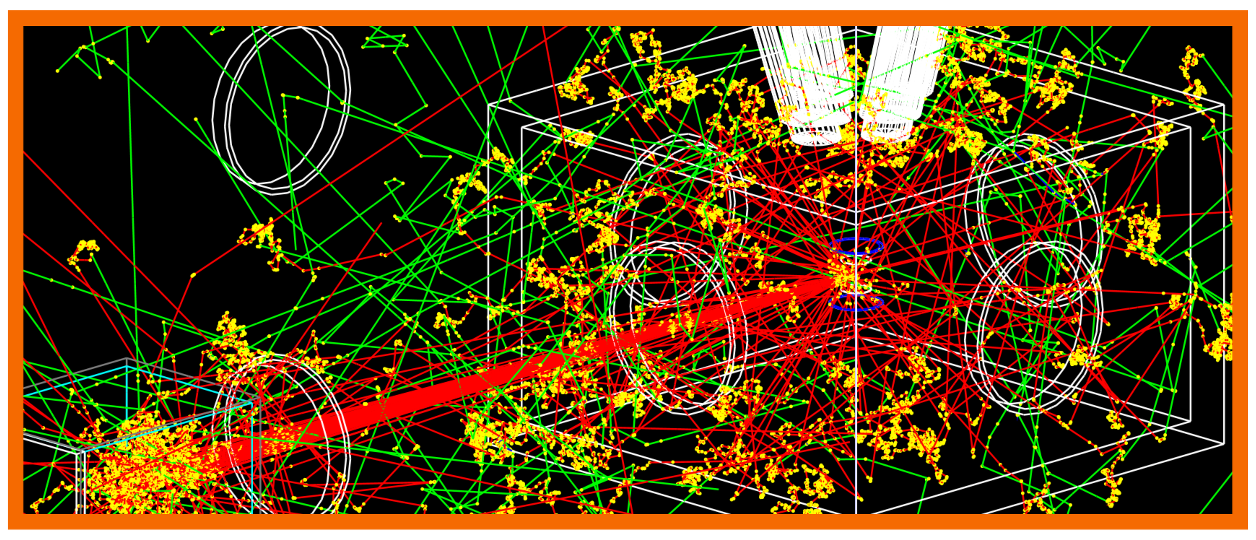

Figure 4. Simulation 1: neutrons produced non-isotropically. 100,000 nuclear events per run. Note that red lines represent neutron trajectories

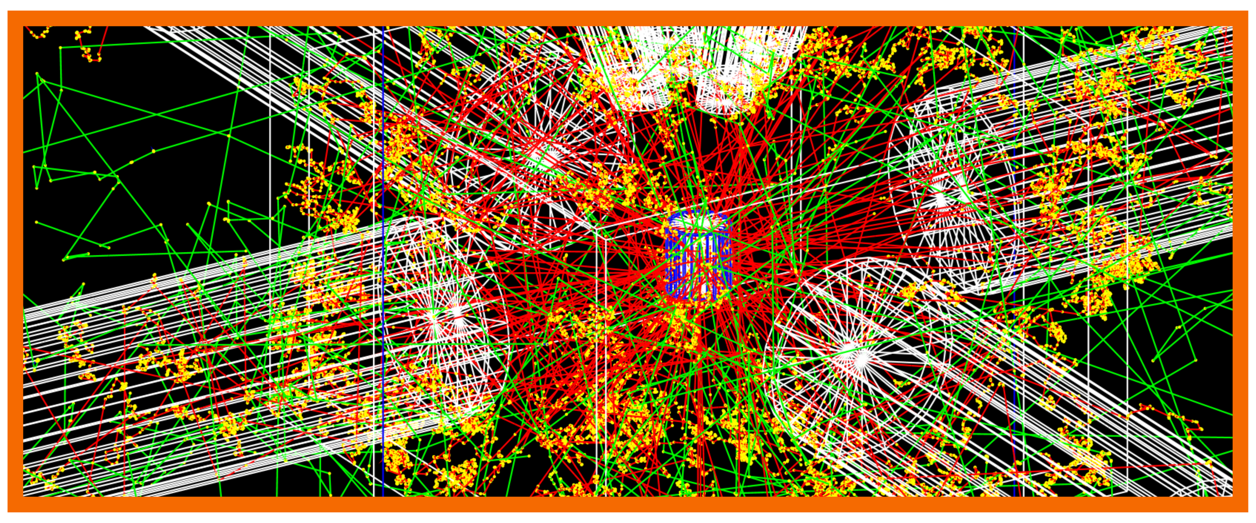

Figure 5. Simulation 2: Quasi-isotropic neutron production. Required additional 400,000 events to ensure significant count rate

4. Discussion

Degree of Isotropy

- Simulation with fully isotropic source would produce more accurate predictions
- Would require simulation of considerable numbers of events and slow down analysis process

Energy Range of Source

- Source produced neutrons in 1-6MeV range
- Proton therapy neutrons can have energies of up to 20MeV
- Could improve relevance of data by using source with wider energy range

Uncertainty in Experimental 'Plug Inserted' Count Value

- Uncertainty large due to low count value
- Uncertainties in associated ratios therefore large
- Recording over longer time period/using stronger source would increase count value and reduce uncertainty

Scaled Neutron Count Values		
Configuration	**Counts**	**Error**
Plug Inserted	390	±298
Plug Removed	520,923	±1550
Detector Displaced	102,994	±527

Table 2. Scaled neutron count values obtained from experiment